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IMAGING IN INTENSIVE CARE MEDICINE

Demonstration of the acute hemodynamic effects of dynamic left ventricular outflow obstruction

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WHAT IS THE CAUSE OF SHOCK?

ICM Intensive Care Medicine

73 year old woman with known history of hypertrophic cardiomyopathy has sudden deterioration in the cardiac intensive care unit with escalating vasopressor requirements. Based on the above images taken 5 minutes apart showing hemodynamic response to 500ml fluid, what is the most likely cause of shock?

What is the cause of shock?

- **A** Hypovolemic shock
- **B** Cardiogenic shock
- **C** Obstructive shock
- **D** Distributive shock
- **E** Mixed shock

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The (Fig. 1A) screenshots were taken 5 min apart with the only intervention being 500 ml fluid bolus. On the left screen, the red arterial line tracing shows the classic spike and dome pattern seen in left ventricular outflow tract

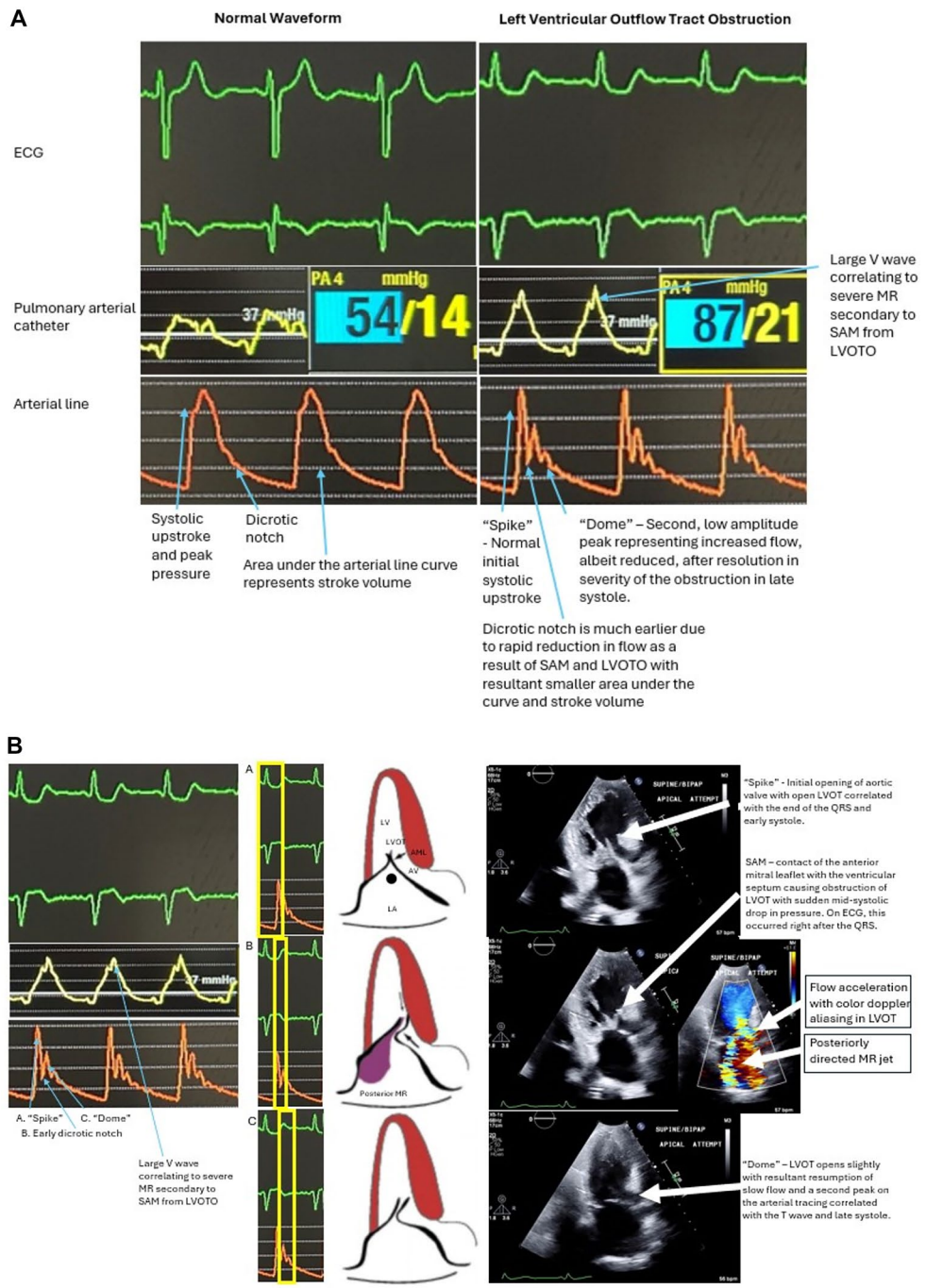
A
Normal Waveform
Left Ventricular Outflow Tract Obstruction
ECG
Pulmonary arterial catheter
Arterial line
PA 4 mmHg
54/14
37 mmHg
PA 4 mmHg
87/21
37 mmHg
Large V wave correlating to severe MR secondary to SAM from LVOTO
Systolic upstroke and peak pressure
Dicrotic notch
Area under the arterial line curve represents stroke volume
"Spike" - Normal initial systolic upstroke
"Dome" – Second, low amplitude peak representing increased flow, albeit reduced, after resolution in severity of the obstruction in late systole.
Dicrotic notch is much earlier due to rapid reduction in flow as a result of SAM and LVOTO with resultant smaller area under the curve and stroke volume
B
A
B
C
37 mmHg
A. "Spike"
B. Early dicrotic notch
C. "Dome"
Large V wave correlating to severe MR secondary to SAM from LVOTO
LV
LVOT
AML
AV
LA
Posterior MR
"Spike" - Initial opening of aortic valve with open LVOT correlated with the end of the QRS and early systole.
SAM – contact of the anterior mitral leaflet with the ventricular septum causing obstruction of LVOT with sudden mid-systolic drop in pressure. On ECG, this occurred right after the QRS.
Flow acceleration with color doppler aliasing in LVOT
Posteriorly directed MR jet
"Dome" – LVOT opens slightly with resultant resumption of slow flow and a second peak on the arterial tracing correlated with the T wave and late systole.

Fig. 1 **A** Comparison of a normal arterial waveform compared to the "spike and dome" pattern seen in LVOT obstruction. Also note the PA line tracing demonstrating the large V wave which correlated with the severe posteriorly directed MR caused by SAM. *V* ventricular, *LVOT* left ventricular outflow tract, *SAM* systolic anterior motion, *MR* mitral regurgitation, *PA* pulmonary artery. **B** Apical 3-chamber view transthoracic echocardiogram images correlated with ECG and arterial line waveform to demonstrate the mitral valve anterior leaflet movement in systole causing contact with the septum and LVOT obstruction. This septal contact of the anterior mitral valve leaflet is called systolic anterior motion (SAM) and causes posteriorly directed mitral regurgitation and the high V wave seen in pulmonary artery catheter tracing. *LV* left ventricle, *LVOT* left ventricular outflow tract, *LA* left atrium, *AV* aortic valve, *AML* anterior mitral leaflet, *MR* mitral regurgitation, *SAM* systolic anterior motion of the mitral valve. Figure adapted from Grigg LE et al. JACC 1992: 20: 42-52

obstruction (LVOTO). After the initial rise in pressure ("Spike") signifying rapid ejection of blood in early systole, there is a mid-systolic drop in pressure caused by the systolic anterior motion of the mitral valve (SAM) causing LVOTO. This is followed by slow blood flow causing a peak in late systole ("Dome"). The yellow pulmonary artery catheter (PAC) tracing demonstrates a large V wave correlating with severe mitral regurgitation, which was posteriorly directed secondary to SAM confirmed on echocardiography. On the right screen, after the fluid administration, there is resolution of the LVOTO arterial tracing pattern with increased area under the curve correlating to improved stroke volume and systemic blood pressure. In addition, there is resolution of the large V wave on PAC tracing. Also note the change in the ECG with evidence of ST elevation in V1 lead and ST depression in lead II, correlating with possible myocardial ischemia. These images demonstrate the dynamic nature of LVOTO and the importance of understanding arterial and PAC waveforms in managing patients with hypertrophic cardiomyopathy with LVOTO.

Takeaway for intensivists

Dynamic LVOT obstruction is an under-recognized cause of shock that is worsened by traditional vasopressor and inotropic support. Prompt recognition of LVOT obstruction based on a combination of evidence from hemodynamic monitor waveforms and echocardiography is crucial to management (Fig. 1B). Management of this condition includes ensuring appropriate left ventricular filling, avoiding chronotropic and inotropic medications, and increasing left ventricular afterload.

Supplementary Information
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Data availability
Not applicable.

Declarations

Conflicts of interest
No competing interests for all authors.

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